

## SUMMARY

Students will learn the sources of some common air pollutants by making pie charts showing the main sources of PM2.5, PM10, nitrogen dioxide (or nitrogen oxides) and sulfur dioxide for the United States as a whole, their state, and their county. They will generate explanations for the similarities and differences among the sources for different geographic areas.

## ESSENTIAL QUESTIONS

- Where do air pollutants come from?
- What can we learn by comparing local sources of air pollution to national sources of air pollution?

## TIME NEEDED

This activity, including the warm up and wrap up, should take about 90 minutes.

## 2012 North Carolina ESSENTIAL STANDARDS FOR EARTH/ENVIRONMENTAL SCIENCE

- 2.5.5 Explain how human activities affect air quality.
- 2.8.2. Critique conventional and sustainable agriculture and aquaculture practices in terms of their environmental impacts.

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## MAKING CONNECTIONS

This activity is yet another example of how displaying data graphically can yield insights that might elude us if data is presented as columns and rows of numbers. Making pie charts allows students to see what proportion of emissions of various air pollutants come from different sources. The pie charts will also make it easier to compare and contrast sources from the United States, North Carolina, and a particular county.

Synthesizing different types of information to draw conclusions is an essential scientific skill. In this activity students will research their state and county in order to generate explanations for the similarities and differences among the charts.

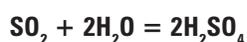
## BACKGROUND

In this activity, students will be focusing on discovering the major sources of emissions of particulate matter, nitrogen dioxide, and sulfur dioxide in the United States, their state, and their county. Students will learn more about the problems caused by these pollutants, as well as about monitoring and setting limits on pollutants, in later activities in this curriculum.

There will be some interesting similarities and differences when comparing pollution sources for the United States as a whole with your county. For example, if your county doesn't have a power plant that burns fossil fuel, electric generation will not be the largest source of sulfur dioxide for your county, although it certainly is for the United States as a whole. The graphs for nitrogen dioxide might look more similar, since cars are the largest source and most counties have plenty of cars. As another example, in rural counties, agriculture might be the largest source of PM<sub>10</sub>, while for the United States as a whole, dust from roads and construction is the largest source of PM<sub>10</sub>.

## PRIMARY AND SECONDARY POLLUTANTS

A primary pollutant is emitted directly from a smokestack, exhaust pipe, chemical vat, or other specific source that can be pointed to. Secondary pollutants, also called area pollutants, are formed when primary pollutants change in the air. Sulfur dioxide (SO<sub>2</sub>) is a great example. It is emitted from a coal smokestack as a primary pollutant. Once in the air, it can react with water to form a secondary pollutant called sulfuric acid (one type of acid rain):



## THE SIX CRITERIA POLLUTANTS

EPA sets the standards for six criteria pollutants: ground-level ozone, particle pollution (also called particulate matter), nitrogen dioxide, carbon monoxide, sulfur dioxide, and lead. Nationally, the levels of all of these pollutants have fallen significantly since 1980, despite the fact that the population, gross domestic product, energy use, and vehicle miles traveled have all risen. However, in many urban areas ozone and particulate matter still pose a challenge.

**Nitrogen dioxide (NO<sub>2</sub>)** is a kind of nitrogen oxide (NO<sub>x</sub>), a class that also includes nitric oxide (NO). NO<sub>x</sub> are formed during combustion in air at very high temperatures (typically 2700°F or higher), such as in a car engine or a boiler at a power plant. NO<sub>x</sub> react with other molecules in the air to produce ground-level ozone, ammonia, nitric acid and acid rain. The largest sources of NO<sub>x</sub> include cars and other vehicles with internal combustion engines, electrical generation, and industry.

**Ground-level ozone** is a secondary pollutant that forms when nitrogen oxides (NO<sub>x</sub>) and volatile organic compounds (VOCs) react in the presence of sunlight and warm temperatures (usually over 75° F). NO<sub>x</sub> comes from burning fuels. VOCs are chemicals containing carbon that evaporate easily – which usually means they are smelly. Sources of VOCs include cleaning chemicals, solvents, paints, unburned gasoline, hog waste lagoons, and natural sources such as trees. In North Carolina, almost all VOCs are from natural sources. Ozone is most likely to form on a hot summer afternoon near cars and in cities.

**Particulate matter** refers to a size rather than a chemical composition. Particulate matter can be either solid particles (such as dust) or tiny liquid droplets. For example, sulfur dioxide and nitrogen oxides can react with other chemicals in the air to form tiny droplets. Particulate matter is divided into two categories. PM<sub>10</sub>, or “coarse” particles, refers to particles less than 10 micrometers in diameter. PM<sub>2.5</sub>, or “fine” particles, refers to particles smaller than 2.5 micrometers. For comparison, fine beach sand is about 90 micrometers in diameter, and a human hair is between 50 and 70 micrometers in diameter. Reactions in the atmosphere among naturally occurring and manmade chemicals (such as sulfur dioxide and nitrogen oxides) are a major source of particulate matter. Other sources of particulate matter include construction sites, unpaved roads, fields, forest fires, and smokestacks.

**Carbon monoxide (CO)** is a product of incomplete combustion. When inhaled, it reduces oxygen delivery in the body. By far vehicles (cars, trucks, construction equipment) contribute the most carbon monoxide in the atmosphere.



**Sulfur dioxide (SO<sub>2</sub>)** is a kind of sulfur oxide (SO<sub>x</sub>). The largest source of sulfur dioxide is fuel combustion during generation of electricity, but it can be generated any time sulfur-rich fossil fuels such as coal are burned. Sulfur dioxide causes health problems, contributes to acid rain, and contributes to particle pollution.

**Lead** in the atmosphere has fallen the most dramatically of the six criteria pollutants, primarily due to the phase-out of leaded gasoline.

## MATERIALS

- Internet connection or hard copy of data
- For each group: (3) 8.4" x 11" sheets of paper, (1) poster board, and markers

## WARMUP

Have your students review the Criteria Pollutants Reference Sheet they used while watching the video about the six criteria pollutants as part of Activity 1-4 (The Criteria Pollutants and a Closer Look at Ozone). As a class, discuss the six criteria pollutants, focusing on how they are formed. Pay particular attention to the pollutants students will be graphing in this activity – PM 2.5, PM 10, nitrogen oxides, and sulfur dioxide – and ask them if they think the major sources of these pollutants will be different for your county compared to North Carolina as a whole and the United States as a whole.

Show your students the video to give them an introduction to the most prevalent air pollution issues in North Carolina. This information gives a larger context for this activity and sets the stage for future activities.

Divide the class into groups of three and assign each group one of the following pollutants: PM2.5, PM10, nitrogen oxides, or sulfur dioxide.



## AIR POLLUTION IN NORTH CAROLINA VIDEO

### IN THIS VIDEO, STUDENTS:

- Are introduced to the major pollution issues in North Carolina including ground-level ozone, particle pollution, acid deposition, mercury deposition, and nitrogen deposition;
- Visit the North Carolina mountains, piedmont and coastal plain to learn about air pollution issues these regions and the sources of the air pollution..
- Hear from the NC Division of Air Quality Director, park rangers, a biomedical researcher, a county air quality official, a riverkeeper, and an air quality expert.

**Video Length:** 10-20 minutes

**Key elements:** video footage and interviews.



## Teacher Tips

**Set-up Time:** 5 Mins.

**Activity Time:** 90-120 Mins.

- I place my students in groups of three and assign one student the U.S. perspective, one the county perspective, and one the North Carolina perspective. They each make their own pie charts and then I have them brainstorm all of their comparisons on a sheet of paper that they turn in with the one-page paper. That way the student that writes the paper has the information they need from the group to make their job more efficient and the grades can be as individualized as possible.
- To save time, have the students use symbols instead of solid colors for the pie charts.

– Mark Townley

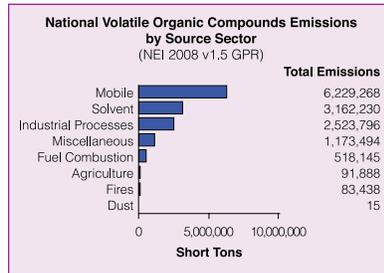
### THE ACTIVITY

You will make three posters showing the sources of your assigned pollutant in (1) the United States, (2) North Carolina, and (3) your county.

#### 1. FIND TOTAL EMISSIONS

- Use the internet (or use information given to you by your teacher) to find data about the main sources of emissions of your assigned pollutant:

**Example of Total Emission Chart**



<http://www.epa.gov/air/emissions/index.htm>

#### 2. CALCULATE PERCENTAGES

- If the information is not already given as percentages, convert it into percentages by adding up the total emissions, then dividing the emissions from each category by the total emissions, and multiplying by 100.

**Example of Calculated Percentage**

$$\begin{aligned} \text{Total Emissions} &= 13,782,274 \\ \text{Mobile} &= 6,229,268 \\ \text{Mobile} \div \text{Total} \times 100 &= 45\% \end{aligned}$$

#### 3. CREATE PIE CHART

- On three 8/5" x 11" sheets of paper, make three pie charts showing the percentages of the emissions that come from each source for the United States, North Carolina and your county. Multiply 360 by the decimal form of each percentage to figure out how many degrees on your protractor you should use to represent each source. For example, if fires account for 3% of the total PM 2.5 emissions, multiply 360 by 0.03 and you'll see that the "fire" slice of the pie should be 10.8 degrees (round up to 11). If there are a number of sources that each account for 2% or less of the total, you may want to lump these into one category called "other sources."
- Make sure to label each pie chart "Sources of \_\_\_\_\_ in the United States," "Sources of \_\_\_\_\_ in North Carolina," or "Sources of \_\_\_\_\_ in \_\_\_\_\_ County." Place the three pie charts on a poster board.
- Include a legend explaining identifying each category, and listing some specific sources in that category. (You can click on the source categories under each bar graph on the EPA website given above to find out specific sources. Example: Dust – unpaved roads, paved roads, construction.) Include illustrations if you like.

#### 4. DISCUSS FINDINGS

- In your group, discuss the differences and similarities among the pie charts for the United States, North Carolina, and your county. Come up with several reasons to explain the similarities and differences.

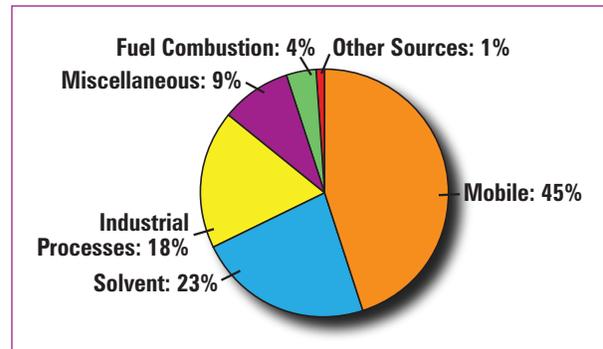
#### 5. WRITE 1-PAGE SUMMARY

- As a group, write a one-page paper comparing and contrasting your three pie charts. If the same category accounts for the largest share of emissions in each pie chart, explain why, using your knowledge of how the pollutant is produced. If there are significant differences among the charts, explain those as well.

#### 6. SHARE FINDINGS

- Choose a representative from your group to share your finding with the class discussing the similarities and differences in the sources for your assigned pollutant in the United States, your state, and your county and possible reasons for those similarities and differences.

**Example of Pie Chart**





## WRAP UP AND ACTION

Display the posters and discuss them as a class. Have representatives from each group discuss the similarities and differences in the sources for their assigned pollutant in the United States, your state, and your county and possible reasons for those similarities and differences. You may wish to display the posters in the school library or other public space.

In a class discussion, ask students how their daily activities influence the emission of the four pollutants depicted in the pie charts.

## ASSESSMENT

### HAVE STUDENTS:

Explain in writing the main sources for nitrogen dioxide, sulfur dioxide, PM2.5 and PM10, and explain, for each of those four pollutants, the reasons behind the similarities and/or differences in the national sources vs. local sources.

## EXTENSIONS

If you and your students are interested in finding out how much and what kind of pollution is emitted by specific businesses, industries, or institutions in your county, you can investigate on [www.scorecard.org](http://www.scorecard.org) or this website hosted by the North Carolina Division of Air Quality:

<https://xapps.ncdenr.org/aq/ToxicsReport/toxrpt.jsp?ibeam=true>

Here are some directions for the scorecard website:

- From the home page, enter your zip code.
- Under "Air," click on "Get a list of the top polluters"
- Select a pollutant (where it says "select your ranking criteria")

## RESOURCES

A good source of information about sources of emissions for a variety of pollutants for the entire US, any state, and any county is on the EPA website. Emissions are given in tons.

<http://www.epa.gov/air/emissions>

For more information on any of the criteria pollutants, see "Basic Information" on the EPA Air Trends website. Choose a pollutant from the list on the left side of the webpage.

<http://www.epa.gov/airtrends/sixpoll.html>

This page on the Division of Air Quality website lists air pollution by facility in each county for a wide variety of pollutants:

<https://xapps.ncdenr.org/aq/ToxicsReport/toxrpt.jsp?ibeam=true>

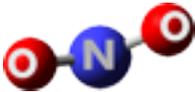
To view the measured concentrations of air pollutants in your county, visit this website of the NC Division of Air Quality: <http://www.ncair.org/monitor/data/>



## Local Sources of Air Pollution



# CRITERIA POLLUTANTS REFERENCE SHEET

NAME	SYMBOL	MOLECULE	SOURCES	PROBLEMS CAUSED
Ozone	O <sub>3</sub>		Combustion, VOC's + NO <sub>2</sub> + sunlight + heat, vehicles, power plants, lightning	Breathing problems for people with lung diseases such as asthma, children, older adults, and people who are active outdoors. Premature death from heart or lung disease.
Particle Pollution or Particulate Matter	PM10 PM2.5	NA	<b>COARSE PARTICLES:</b> <10 micrometers – dust storms, mining. <b>FINE PARTICLES:</b> <2.5 micrometers – chemical processes, combustion, factories, power plants, vehicles	When inhaled can cause serious health problems and premature death. In air can cause visual haze.
Nitrogen Dioxide	NO <sub>2</sub> (NOX)		Combustion, vehicles, power plants	Makes asthma worse and increases respiratory illnesses. Contributes to ground-level ozone, acid rain, nutrient overloading in streams and lakes.
Carbon Monoxide	CO		Vehicles, industrial processes, residential wood burning, forest fires	At low levels-harmful to people with heart conditions. At high levels-poisonous, can kill you.
Sulfur Dioxide	SO <sub>2</sub>		Burning coal or oil that contains sulfur	Breathing problems. Contributes to acid rain and particle pollution.
Lead	Pb	NA	Historically – vehicles Currently – lead smelters	Inhaling lead is harmful to brain function in children and cardiovascular disease in adults.



# Local Sources of Air Pollution

Student Page #2

## THE ACTIVITY

### Assigned Pollutant: \_\_\_\_\_

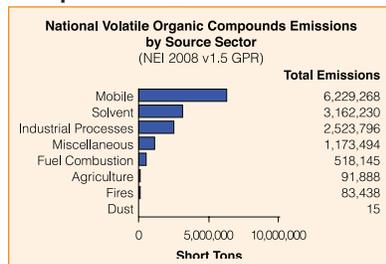
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#### Example of Total Emission Chart



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- If the information is not already given as percentages, convert it into percentages by adding up the total emissions, then dividing the emissions from each category by the total emissions, and multiplying by 100.

#### Example of Calculated Percentage

**Total Emissions = 13,782,274**  
**Mobile = 6,229,268**  
**Mobile ÷ Total x 100 = 45%**

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